CALIFORNIA DEPARTMENT OF FISH AND GAME
WATER AND AQUATIC HABITAT CONSERVATION BRANCH
Stream Evaluation Program

1998 Upper Sacramento River Winter-Run Chinook Salmon Escapement Survey May - August 1998[1/]

by

Bill Snider
Bob Reavis
and
Scott Hill

Stream Evaluation Program
Technical Report No. 99-1
March 1999

CALIFORNIA DEPARTMENT OF FISH AND GAME
WATER AND AQUATIC HABITAT CONSERVATION BRANCH
Stream Evaluation Program

1998 Upper Sacramento River Winter-Run Chinook Salmon Escapement Survey May - August 1998[1/,2/]

by

Bill Snider
Bob Reavis
and
Scott Hill

March 1999

1/ This was a cooperative investigation with U.S. Fish and Wildlife Service, Northern Central Valley Fish and Wildlife Office. Funding was provided by the U.S. Fish and Wildlife Service, Central Valley Anadromous Fish Restoration Program as part of a cooperative agreement with the California Department of Fish and Game pursuant to the Central Valley Project Improvement Act (PL. 102-575).

2/ Stream Evaluation Program Technical Report 99-1.

SUMMARY

The California Department of Fish and Game's (DFG) Stream Evaluation Program and the US Fish and Wildlife Service's (FWS) Northern Central Valley Fish and Wildlife Office (NCVFWSO) jointly conducted a winter-run chinook salmon *Oncorhynchus tshawytscha* escapement survey in the upper Sacramento River during spring-summer 1998. Data were acquired on spawner abundance, age and sex composition of the spawner population, pre-spawning mortality, and temporal and spatial distribution of spawning activity. The survey was conducted from 5 May through 28 August 1998. It covered the uppermost 14 miles of the Sacramento River accessible to migrating salmon, from river mile 288 (RM 288) upstream to Keswick Dam (RM 302). This was the third consecutive year a winter-run escapement survey was conducted as part of a multi-year investigation to determine salmon habitat requirements in the Sacramento River system.

Flow steadily increased from 10,000 cubic feet per second (cfs) at the start of the surveys (5-6 May) to 23,500 cfs on 29-30 May, then decreased to 12,600 cfs on 10-11 June. Flow then fluctuated between 14,000 and 15,200 cfs for the remainder of the survey. Water clarity (Secchi depth) ranged from 4.5 to 7.4 ft throughout May and June, and from 7.1 to 10.8 ft during the remainder of the survey. Water temperature ranged from 50 ^{o}F to 54 ^{o}F (mode = 52 ^{o}F). Most spawning (~70%) occurred from early June into late July. Peak spawning occurred during late June, two weeks prior to the peak in fresh carcass counts.

A total 785 carcasses (382 fresh and 403 decayed) were collected. All but eight of the fresh carcasses were sexed and measured. Based upon length frequencies, 98% of the measured carcasses were adults and 2% were grilse (all males). Overall, 12% of the measured carcasses were male and 88% were female; 10% of the adults were male and 90% were female. Ninety-five percent of 327 females checked for egg retention had completely spawned. Coded-wire tags (CWT) were recovered from two fresh carcasses with adipose-fin marks. The CWT data revealed that both fish were winter-run salmon released from Coleman National Fish Hatchery: one each from the 1994 and 1995 brood years.

Spawner escapement estimates were made using a carcass mark-and-recapture method. A total of 371 fresh carcasses was tagged and 56 (15%) were subsequently recovered. Based on fresh carcass data, the Petersen model yielded an estimate of 5,391 adults. The total salmon population (adults plus grilse) was estimated by expanding the adult estimate based upon the observed proportion of fresh adult and grilse carcasses (98% and 2%). The total population estimate was to 5,501 (5,391 adult and 160 grilse). The Schaefer model was also used after being altered to account for the lack of tags being recovered from 16 of the 38 survey periods. The Schaefer escapement estimate was 4,653, (4,560 adult and 93 grilse). The effective spawner population estimates were 4,609 (Petersen) and 3,899 (Schaefer) females.

The 1998 winter-run escapement estimate based on counts made at Red Bluff Diversion Dam (RBDD) (RM 243) was 1,784 adults and 828 grilse. A discussion of the RBDD estimates and the carcass survey results is provided.

INTRODUCTION

A winter-run chinook salmon *Oncorhynchus tshawytscha* escapement survey was conducted in the upper Sacramento River during spring-summer 1998 to acquire data on spawner abundance, age and sex composition of the spawner population, pre-spawning mortality, and temporal and spatial distribution of spawning. This was the third consecutive year a winter-run escapement survey was conducted as part of a multi-year investigation to determine salmon-habitat requirements in the Sacramento River system (Snider *et al*. 1998). A fundamental component of the investigation is the identification of salmon-habitat relationships at all life stages, including spawning for all salmon runs in the system. Also, since spawning habitat investigations can be influenced by both spawner abundance and habitat availability, it is important that spawner population surveys and habitat monitoring be conducted concurrently to distinguish the influences of these two factors on habitat use.

Escapement surveys conducted concurrently with redd surveys have been successfully used in the lower American River to identify relationships between spawning habitat availability and flow (Snider and McEwan 1992, Snider *et al*. 1993, Snider and Vyverberg 1995). The investigations on the lower American River strongly suggest that relationships between water temperature and temporal distribution of spawning and emergence, spawner abundance and pre-spawning mortality, flow and habitat availability, spawner abundance and habitat use as well as innate variability in expressed life history attributes can all influence the interpretation of salmon-habitat investigations. Thus, based upon our experiences in evaluating salmon-habitat relationships on the lower American River, we concluded that spawner escapement surveys should be conducted on the upper Sacramento River.

The 1996 and 1997 surveys were the first attempts to use carcass mark-and-recapture techniques to estimate winter-run chinook salmon escapement in the Sacramento River. Carcass mark-and-recapture surveys have been routinely used to estimate escapement to other Sacramento Valley tributary streams (e.g., American, Yuba, and Feather rivers and Battle Creek). This method was initially used in the Central Valley to estimate the 1973 Yuba River escapement (Taylor 1974). Three models have been used by the DFG to estimate escapement from carcass mark-and-recapture data: Petersen (Ricker 1975), Schaefer (1951), and the Jolly-Seber (Seber 1982). The Petersen model is the simplest but least accurate and has been used primarily when data are insufficient to allow calculation with other models. It is occasionally used to calculate estimates for smaller salmon populations in other Central Valley tributary streams (e.g., Cosumnes, Merced, Stanislaus, and Tuolumne rivers). A modified Schaefer model has been used in Central Valley tributary streams supporting “larger” salmon populations since 1973 when it was first used to estimate the Yuba River escapement. The Jolly-Seber model was first used in the Central Valley in 1988 to estimate escapement in the Feather, Yuba, American, Stanislaus, Tuolumne, and Merced rivers.

Evaluation of winter-run spawning in the Sacramento River is an integral part of an agreement between the DFG and the FWS’s Central Valley Anadromous Fish Restoration Program to determine habitat requirements for anadromous salmonids in Central Valley streams. Studies being implemented by the DFG will provide the FWS with reliable scientific information for development of flow recommendations and satisfy requirements of the Central Valley Project Improvement Act, Section 3406(b)(1)(B). The Sacramento River was selected for intensive fish-habitat investigations due to the significant influence the Central Valley Project has upon flow, temperature and ultimately fish habitat in the river. Furthermore, the upper Sacramento River is the only stream reach in the Central Valley that supports all four chinook salmon runs and steelhead. The exclusive occurrence of winter-run chinook salmon - a federally and state listed species - and the presence of rapidly disappearing Central Valley steelhead (listed as threatened under the federal Endangered Species Act in March 1998) underscore the significance of habitat in this stream reach.

Results of the carcass survey may be used for comparison and augmentation of data collected on winter-run migration at the Red Bluff Diversion Dam (RBDD). Similarly, the survey could augment weekly winter-run-redd surveys. The NCVFWSO and Coleman National Fish Hatchery (CNFH) could also use the results to evaluate their winter-run-escapement augmentation program using winter run spawned and reared at CNFH (USFWS 1996, Croci and Hamelberg 1997).

Objectives

The objectives of the 1998 winter-run chinook salmon spawner escapement survey were:

- To estimate the in-river, winter-run chinook salmon population in the upper Sacramento River based on a carcass mark-recapture survey and augment estimates that are based on RBDD counts.

- To continue examination of the feasibility of using mark-recapture techniques (i.e., Peterson, Jolly-Seber, and Schaefer population models) to estimate winter-run escapement in the upper Sacramento River, and recommend future escapement estimating procedures.

- To obtain baseline information on spawning distribution (spatial and temporal), environmental conditions at the time of spawning, and the spawning population (length frequency, age, sex composition, and spawning success) to eventually identify winter-run spawning habitat requirements in the upper Sacramento River.

Background

Winter run is one of four chinook salmon runs present in California's Central Valley. The other three runs are fall, late-fall, and spring. Winter run generally leave the ocean and enter fresh water to begin their upstream migration from December through June. The peak of the run normally passes RBDD in March and April. Winter run typically spawn from mid-April through mid-August.

The earliest references to winter-run salmon have been described by Fisher (1993). In 1874, Livingston Stone noted winter run in the McCloud River, a tributary to the Sacramento River that presently drains into Shasta Lake. Winter-run status since the construction of Shasta Dam has been described by Slater (1963), Hallock and Fisher (1985), and Fisher (1993). Since Shasta Dam has blocked winter run access to most of their historic spawning habitat, they now predominantly spawn immediately downstream of Keswick Dam, the upstream barrier to migration in the Sacramento River (Figure 1). Due to a drastically declining population, winter run were listed as endangered by the California Fish and Game Commission in 1989, as threatened by the National Marine Fisheries Service (NMFS) in 1990, and then as endangered in 1994.

The NMFS (1996) has developed a winter-run extinction model that identifies population conditions corresponding to an acceptable low probability of population extinction. Using the model, NMFS determined that the population will have recovered when the mean annual spawning abundance over any 13 consecutive years is at least 10,000 females. This population level assumes that the male:female ratio is 1:1 and that the age structure is comparable to that observed by Hallock and Fisher (1985) over three brood years. The assumed age structure is 50% 2-year-olds, 44% 3-year-olds, and 6% 4-year-olds for males, and 89% 3-year-olds and 11% 4-year-olds for females. The population criteria also assume that annual escapement will be estimated with a precision of ±25%.

Since 1969, winter-run escapement estimates have been based upon counts of salmon using fishways that provide passage over RBDD. Counts can only be made when the diversion is in operation, (i.e., the gates are down) and all fish migrating above RBDD are forced to use the fishways located in the center and on the east and west ends of the dam. From 1969 through 1985, RBDD was typically operated throughout the entire winter-run migration period allowing a complete accounting of winter-run escapement. Unfortunately, RBDD hampers upstream migration when the gates are down and fish are migrating through the ladders. As such, beginning in 1986, the operation of RBDD was modified to improve winter-run migration. Now, the gates are typically raised from mid-September through mid-May the following year to allow most winter run unimpeded upstream passage. Since the diversion now is only operated between mid-May and mid-September, only a small portion of the winter-run migration is typically affected by the operation and thus, counted moving through the fishways.

Annual winter-run escapement is now estimated by expanding the abbreviated-season count, assuming it is proportionate to historic, entire-season counts (pre-1986). The proportion used to expand the abbreviated count is based upon the date the diversion is placed in operation and counts are initiated. The total season count is estimated by dividing the count made after the start date by the mean fraction of the total population that passed RBDD after that date when counts were season-long.

The procedures used to count salmon in the RBDD fishways include a combination of actual daytime counts (east and west fishways) and counts made from daytime video recordings (center fishway). Fish using the east and west ladders are counted directly through viewing facilities from 0600 h to 2000 h each day of the season. Fish using the center ladder are counted and identified by reviewing video tapes made from 0600 h to 2000 h each day of the season. Once a week, the DFG determines night passage at the east and west ladders by extending the direct counts from 2000 h to 2200 h and then video taping passage from 2200 h to 0600 h the next morning to identify and count fish that had passed. The single night count is used to determine a correction factor to account for night passage for all other nights of the week. The DFG also operates a fish trap located in the east fish ladder. The trap is typically operated 7 days a week through July, then 5 days a week through mid-September, from 0600 h to 1500 h, and only when water temperatures are $\leq 60^{o}$ F. Trapped fish are identified to species or, if a salmon, to run based upon appearance (i.e., morphological signs of sexual maturity). Fish are measured and checked for marks (e.g., adipose-fin clips).

METHODS

The NCVFWSO and the DFG's Stream Evaluation Program jointly conducted a mark-and-recapture carcass survey to estimate the number of winter-run chinook salmon spawning in the upper Sacramento River. The survey was carried out from 5 May 1998 through 28 August 1998. Methods were similar to those used during the 1997 winter-run-escapement survey (Snider *et al*. 1998).

In 1996, the survey reach extended 31 miles from Keswick Dam (RM 302) downstream to Battle Creek (RM 271) (Figure 1), which was considered the primary spawning area for winter run in the upper Sacramento River. The 1996 results, however, indicated that over 90% of winter-run spawning activity occurred in the upper 14 miles of the 31-mile survey reach. At the same time, the tag recovery rate was low (15%). As such, we decided to shorten the study reach to the 14 mile reach immediately downstream from Keswick Dam to allow increasing survey frequency in an attempt to increase recovery rates. In 1997, the study area was divided into two 7-mile reaches and each of these reaches was surveyed an average of 2.5 times per week. This change was intended to provide an adequate coverage of most of the area used by winter run to spawn and increase our tag recovery rate which in turn would provide a more accurate escapement estimate. This was continued in 1998.

The study section was divided into the following two reaches:

1. Keswick Dam to Cypress Street Bridge - RM 302 to RM 295, and

2. Cypress Street Bridge to Redding Water Treatment Plant - RM 295 to RM 288.

The upper reach was surveyed on the first day and the lower reach on the second day of each 2-day survey period. Then one day was skipped and the cycle repeated. Most of the survey effort was conducted by boat (two boats and two observers per boat). Each boat was generally used to survey along one shoreline out to the middle of the river. There were several short stretches of river that were surveyed on foot. Survey effort was intensified in areas where carcasses were known to collect. Most observed carcasses were collected using a gaff or gig, then sexed, measured and tagged, as described below.

Flow measurements from the Keswick gauge were obtained from the U.S. Geological Survey. Water temperatures and water clarity (Secchi disk) readings were measured daily by the survey crew.

Population Estimates

The winter-run spawner population was estimated using a mark-and-recapture (tag-and-recovery) method. Most collected carcasses were tagged except those in an advanced state of decay. Carcasses not tagged were counted then cut in two (chopped). All chopped carcasses were disregarded in subsequent surveys. Carcasses were tagged by attaching a small colored plastic ribbon to the upper or lower jaw with a hog ring. The tag color was used to later identify the survey period that the carcass was initially tagged. Fresh carcasses (those with firm flesh and at least one clear eye) were tagged in the upper jaw. Decayed carcasses were tagged in the lower jaw. Carcass condition was noted during tagging to accommodate the various population estimators. Based on DFG protocol, results from fresh carcass data are used to calculate an escapement estimate using the Schaefer model, and results from both fresh and decayed data are used to calculate an estimate using the Jolly-Seber model. All tagged carcasses were returned to flowing water near where they were collected in an attempt to simulate “natural” carcass dispersion. Recovered, previously tagged carcasses were examined for tag color, location of tag (upper or lower jaw), and age (based on size). The pertinent data were recorded and the carcass was chopped.

The Petersen (Ricker 1975) and Schaefer (Schaefer 1951) models were used to calculate estimates from the 1998 tagging results. The Jolly-Seber (Seber 1982) was not used since it requires that there be tag recoveries from all tagging periods.

The adjusted Petersen formula (Ricker 1975) used to calculate an escapement estimate is as follows:

$$N = \frac{(M+1)(C+1)}{(R+1)}$$

Where:

N	=	Population size,
M	=	total number of carcasses tagged,
C	=	total number of examined, and
R	=	total recaptures of tagged carcasses in the *j*th recovery period.

The modified Schaefer formula (Schaefer 1951 as modified by Taylor 1974) used to calculate an escapement estimate is as follows:

$$N = \sum (R_{ij})\left(\frac{M_i}{R_i}\right)\left(\frac{C_j}{R_j}\right) - \sum_{i=2}^{n} M_i$$

Where:

N	=	Population size,
R_{ij}	=	number of carcasses tagged in the *i*th tagging period and recaptured in the *j*th recovery period,
M_i	=	number of carcasses tagged in the *i*th tagging period,
C_j	=	number of carcasses recovered and examined in *j*th recovery period,
R_i	=	total recaptures of carcasses tagged the *i*th tagging period, and
R_j	=	total recaptures of tagged carcasses in the *j*th recovery period.

These models were used to estimate the adult population using only data pertaining to adult-sized carcasses (e.g., number of fresh/decayed, adult-sized carcasses tagged, recovered, chopped, etc.) The total salmon population (adult plus grilse) was estimated by expanding the adult estimate in proportion to the percentage of adult-sized carcasses observed in the survey. For example, if the percentage of adult sized carcasses was 80%, the adult escapement estimate (obtained from the model) was divided by 0.80 to estimate the total population. The grilse population estimate was obtained by subtracting the adult estimate from the total estimate.

Size/age Distribution and Sex Composition

Fork length (FL), sex, and date of collection were recorded for most measurable carcasses. (Some carcasses were too deteriorated to allow accurate measurements). The length-frequency distribution of each sex was used to define the length separating adults (>2-years old) and grilse (2-year-olds). Since results from fresh carcasses better represent the population, we only used fresh carcass data to develop length-frequency relationships and sex ratios.

Spawning Success

Most measurable female carcasses were checked for egg retention. Females were classified as spent, if few eggs remained, as partially spent if a substantial amount (i.e., 50% or more) of eggs still remained in the body cavity, and unspent if they appeared to be completely unspawned.

Temporal Distribution

Fresh carcasses were assumed to become available to sampling within two weeks of spawning completion, based upon observations made in the American River (Snider and Vyverberg 1995). The total number of fresh carcasses observed in both reaches during each survey period was used to describe temporal spawning distribution.

Spatial Distribution

The total number of fresh carcasses observed in each survey reach was used to define season-long geographic distribution of spawning activity. Flow likely carried some carcasses from the upstream reach, where spawning occurred, to the downstream reach, where recovery occurred, potentially biasing the spatial distribution of spawning toward the downstream reach.

Hatchery-produced Winter-run Chinook Salmon

Carcasses were also checked for adipose-fin clips, indicating the fish was of hatchery origin and possessed a coded-wire tag (CWT). Heads were collected from clipped carcasses and the CWTs were later extracted and codes read.

RESULTS

General

A total of 382 fresh and 403 decayed carcasses were observed during the 39 survey periods (Table 1). Mean flow during the 39 survey periods ranged from 10,000 to 23,500 cfs (Figure 2). Mean survey-period temperature ranged from 50^{o} to 54^{o} F. Secchi depth readings ranged from 4.5 to 10.8 ft and generally increased as the survey season progressed.

Population Estimates

The Peterson (Ricker 1975) and Schaefer (1951 as modified by Taylor 1974) models were used to estimate escapement. The Jolly-Seber model was not used because it requires tag recoveries from each tag group released. A total of 371 fresh adult carcasses was tagged and 56 (15%) were subsequently recovered (Table 2). A total of 199 decayed carcasses was tagged and 19 (10%) were subsequently recovered.

The Peterson formula was used by combining the season-long totals for adult carcasses. Two estimates were calculated; one using only fresh carcass-recovery data, and one using all carcass-recovery data. An estimate of 5,391 adults was calculated using fresh carcass data. Assuming 98% of the populations were adults (based on length-frequency data results described later in this report), the total population estimate was 5,501 (Table 2). A second estimate of 6,349 adults was calculated using data from all tagged carcasses. This was similarly expanded to a total population estimate of 6,479. Based on Law's (1994) analysis, the estimate based on fresh carcass data is more accurate.

The Schaefer formula was not used to estimate spawner escapement in 1996 and 1997 since no tags were recovered during a substantial number of the survey periods. Similarly, in 1998, no tags were recovered during 16 of the 38 survey periods. However, due to the repetitive occurrence of this situation, we modified our application of the 1998 data to enable use of the Schaefer model. Estimates were calculated for survey periods when no tags were recovered by using fresh-carcass tagging results and assuming the recovery rates for such periods were equal to the mean of the preceding and succeeding periods when tags were recovered. For the start of the survey, the recovery rate of the fourth recovery period (the first period that tags were recovered) was used to expand the numbers observed in the first three recovery periods. For the end of the season, the numbers of carcasses observed during the 36th through 39th surveys were expanded by the recovery rate of the 35th survey period (the last period tags were recovered). The escapement estimate using this modified application of the Schaefer model was 4,560 adults. The total population estimate was 4,653.

Table 1. Summary of mean flow, mean water temperature, Secchi depths, and carcass count totals during each survey period of the upper Sacramento River winter-run chinook salmon escapement study, May - August 1998.

Survey period	Dates	Mean flow (cfs)[1/]	Mean water temperature (° F)[2/]	Mean Secchi depth (ft)	Carcasses count[3/]	
					Fresh	Decayed
1	May 5-6	10,000	52	5.0	6	9
2	May 8-9	10,000	52	5.0	8	1
3	May 11-12	12,500	50	5.2	6	8
4	May 14-15	13,700	52	7.4	7	9
5	May 17-18	14,700	52	6.8	10	9
6	May 20-21	14,900	52	5.8	4	7
7	May 23-24	18,000	53	6.8	7	3
8	May 26-27	18,000	52	6.9	10	6
9	May 29-30	23,500	53	4.5	0	1
10	June 1-2	19,500	54	6.6	3	6
11	June 4-5	19,500	52	7.0	5	7
12	June 7-8	16,800	52	6.2	8	7
13	June 10-11	12,600	52	5.7	12	30
14	June 13-14	14,000	52	5.0	11	9
15	June 16-17,	14,700	51	5.4	13	11
16	June 19-20	15,200	52	6.6	15	17
17	June 22-23	15,000	51	6.6	17	22
18	June 25-26	14,500	52	7.4	22	14
19	June 28-29	14,400	51	7.0	26	16
20	July 1-2	14,400	52	7.2	30	32
21	July 4-5	14,900	52	8.0	24	18
22	July 7-8	15,200	52	8.2	16	14
23	July 10-11	14,900	52	7.4	17	11
24	July 13-14	14,700	52	7.7	24	22
25	July 16-17	14,800	54	8.4	13	13

Table 1 (cont.). Summary of mean flow, mean water temperature, Secchi depths, and carcass count totals during each survey period of the upper Sacramento River winter-run chinook salmon escapement study, May - August 1998.

Survey period	Dates	Mean flow (cfs)[1/]	Mean water temperature (° F)[2/]	Mean Secchi depth (ft)	Carcasses count[3/]	
					Fresh	Decayed
26	July 19-20	14,800	54	8.2	10	10
27	July 22-23	14,700	52	7.1	11	12
28	July 25-26	14,600[4/]	52	7.2	4	6
29	July 28-29	14,800	52	8.4	6	22
30	July 31-Aug 1	15,000	52	8.4	7	8
31	August 3-4	15,000	53	7.8	13	10
32	August 6-7	14,600	52	9.4	6	14
33	August 9-10	14,700	52	9.0	4	2
34	August 12-13	14,700	54	9.2	1	2
35	August 15-16	14,600	54	8.8	3	5
36	August 18-19	14,900	52	9.2	1	5
37	August 21-22	14,800	52	8.8	1	1
38	August 24-25	14,600	52	10.8	1	3
39	August 27-28	14,300	52	10.6	0	1
				Totals -	382	403

1/ Mean flow at Keswick Dam during survey period as measure by U.S. Geological Survey.
2/ Mean water temperature measured each day by survey crew.
3/ Includes grilse and adults; does not include tag recoveries.
4/ No flow measurement recorded for 25 July 1998.

Table 2. Summary for each tagging period of number observed (fresh and decayed), tagged (fresh), and recaptured (fresh) during 1998 upper Sacramento River winter-run chinook salmon escapement survey, May - August 1998.

Tagging period	Date	Number observed		Number tagged		Number recovered (Original tagging period)
		Adults	Grilse	Adults	Grilse	
1	May 5-6	15	0	6	0	0
2	May 8-9	9	0	8	0	0
3	May 11-12	14	0	5	0	0
4	May 14-15	15	1	7	0	0
5	May 17-18	19	0	10	0	1(4)
6	May 20-21	11	0	4	0	2(5),1(4)
7	May 23-24	9	1	6	1	0
8	May 26-27	16	0	9	0	2(7),1(6),
9	May 30-31	1	0	0	0	0
10	June 1-2	9	0	2	0	0
11	June 4-5	12	0	5	0	0
12	June 7-8	15	0	8	0	0
13	June 10-11	40	2	11	1	0
14	June 13-14	20	0	11	0	1(13)
15	June 16-17	24	0	13	0	2(14)
16	June 19-20	31	1	14	1	0
17	June 22-23	38	1	17	1	1(15),1(13)
18	June 25-26	36	0	22	0	5(17)
19	June 28-29	42	0	26	0	1(18)
20	July 1-2	60	1	30	0	1(19),1(18)
21	July 4-5	42	0	24	0	3(20),1(19)
22	July 7-8	30	0	16	0	2(21),1(19)
23	July 10-11	26	2	16	1	5(22),2(21)
24	July 13-14	43	3	23	1	1(23),3(22),2(21)
25	July 16-17	26	0	13	0	3(24),1(23),1(21)

Table 2 (cont.). Summary for each tagging period of number observed (fresh and decayed), tagged (fresh), and recaptured (fresh) during 1998 upper Sacramento River winter-run chinook salmon escapement survey, May - August 1998.

Tagging period	Date	Number observed		Number tagged		Number recovered (Original tagging period)
		Adults	Grilse	Adults	Grilse	
26	July 19-20	20	0	9	1	0
27	July 22-23	22	1	11	0	1(26)
28	July 25-26	10	0	4	0	0
29	July 28-29	27	2	6	1	1(28)
30	July 31 - August 1	15	0	7	0	1(26)
31	August 3-4	23	0	13	0	1(30),1(29),1(28),1(26)
32	August 6-7	20	0	6	0	1(31),1(30)
33	August 9-10	6	0	4	0	2(32),1(29)
34	August 12-13	3	0	1	0	1(32),1(31)
35	August 15-16	8	0	1	0	1(34)
36	August 18-19	5	1	1	0	0
37	August 21-22	2	0	1	0	0
38	August 24-25	4	0	0	0	0
39	August 27-28	1	0	0	0	0
Totals		769	14	371	5	56

* All were adults, no grilse were recovered.

Size/Age Distribution and Sex composition

A total of 374 carcasses was measured (Table 3). Mean FL was 68.8 cm (range: 45-102 cm FL). Male salmon (n = 44) averaged 73.7 cm FL (range: 45-92 cm FL). Female salmon (n = 330) averaged 68.1 cm FL (range: 55-102 cm FL). The largest fish were observed during the first month. The mean size of males narrowly ranged from 74.7 to 76.0 cm FL during May, June, and August (Figure 3). The mean size of males was smaller during July (62.7 cm FL) when three of the seven measured males were grilse. The mean monthly size of females was the greatest during May (71.2 cm FL), and narrowly ranged from 67.5 to 67.9 cm FL for the remainder of the survey.

The female and male length frequency distributions were quite different (Figure 4). About 98% of the females were grouped in a normal distribution that ranged from 55 to 79 cm FL with a mode of 66 cm FL. These fish were likely all 3-years old. The remaining 2% of the female population ranged from 84 to 102 cm FL and were likely 4-years old. The male distribution was discontinuous exhibiting a relatively large gap between 57 cm FL and 63 cm FL (Figure 4). We used these data to define 60 cm FL as the size criterion separating male grilse (2-year-old salmon) and male adults (>2-year-old salmon). We plan to verify the age/length relationship for the 1998 spawner population using scales and otoliths taken from most measured carcasses.

Male grilse averaged 51.6 cm FL (SD = 4.3; range: 45-57 cm FL) (Table 4). Male adults averaged 77.9 cm FL (SD = 6.8; range: 63-92 cm FL). Female adults averaged 68.1 cm FL (SD = 6.1; range 55-102 cm FL). As previously stated, no female grilse were observed.

Ninety-eight percent (n = 367) of the fresh carcasses measured were adults and 2% (n = 7) were grilse (Table 5). At least 96% of the carcasses observed each month were adults.

All grilse were males which made up only 2% of the total population and 16% of the male population (Table 6). The adult sample comprised 90% (n = 330) females and 10% (n = 37) males. The ratio of male to female adult spawners was 1 to 8.9. The overall sex ratio, including grilse, was 1to 7.5.

Spawning Success

Ninety-five percent (n = 310) of the 327 fresh female carcasses examined for egg retention had completely spawned. Two percent (n = 7) had partially spawned, and 3% (n = 10) had not spawned. Unspawned and partially spawned females were observed throughout the survey.

Table 3. Size and sex statistics for winter-run chinook salmon carcasses measured during upper Sacramento River escapement survey, May - August 1998.

	All salmon			Male salmon			Female salmon		
		Length (FL in cm)			Length (FL in cm)			Length (FL in cm)	
Month	Number measured	Mean	Range	Number measured	Mean	Range	Number measured	Mean	Range
May	57	72.7	51-102	17	76.0	51-87	40	71.2	59-102
June	127	68.9	45-97	18	74.7	45-92	109	67.9	56-97
July	162	67.4	47-86	7	62.7	47-81	155	67.5	55-86
August	28	68.2	57-102	2	76.0	71-81	26	67.6	57-102
Total (mean)	374	68.8	45-102	44	73.7	45-92	330	68.1	55-102

Table 4. Summary of adult and grilse size and number by sex for winter-run chinook salmon carcasses measured during the upper Sacramento River escapement survey, May - August 1998.

	Female		Male	
	Grilse	Adults	Grilse*	Adults
Total measured	0	330	7	37
Mean	-	68.1	51.6	77.9
Range FL (cm)	-	55-102	45-57	63-92
SD	-	6.1	4.3	6.8

* Grilse were defined as male salmon $\leq$ 60 cm FL.

Table 5. Age composition (grilse and adult) of winter-run chinook salmon carcasses measured during the upper Sacramento River spawner escapement survey, May - August 1998.

Month	Adults		Grilse	
	Number	%	Number	%
May	55	96	2	4
June	125	98	2	2
July	159	98	3	2
August	28	100	0	0
Totals (mean)	367	(98)	7	(2)

Table 6. Sex composition of winter-run chinook adult and grilse carcasses measured during the upper Sacramento River escapement survey, May - August 1998.

	Adults				Grilse			
	Male		Female		Male		Female	
Month	Number	%	Number	%	Number	%	Number	%
May	15	27	40	77	2	100	0	0
June	16	13	109	87	2	100	0	0
July	4	3	155	97	3	100	0	0
August	2	7	26	93	0	-	0	-
Totals (mean)	37	(10)	330	(90)	7	(100)	0	(0)

Table 7. Summary of salmon carcass distribution observed during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1998. Summary includes fresh and decayed, adults and grilse carcasses but not tag recoveries.

	Reach 1		Reach 2	
Survey period	Fresh	Decayed	Fresh	Decayed
1	2	4	4	5
2	5	1	3	0
3	2	3	4	5
4	5	2	2	7
5	2	2	8	7
6	0	3	4	4
7	3	1	4	2
8	4	2	6	4
9	0	0	0	1
10	0	1	3	5
11	2	7	3	0
12	3	1	5	6
13	4	15	8	15
14	3	5	8	4
15	2	8	11	3
16	11	6	4	11
17	12	9	5	13
18	12	8	10	6
19	10	7	16	9
20	24	21	6	11
21	14	15	10	3
22	8	11	8	3
23	11	2	6	9
24	16	12	8	10
25	11	6	2	7
26	6	6	4	4
27	9	6	2	6
28	2	5	2	1
29	6	20	0	2
30	6	7	1	1
31	11	8	2	2
32	5	11	1	3
33	3	0	1	2
34	1	2	0	0
35	3	4	0	1
36	1	5	0	0
37	1	1	0	0
38	1	2	0	1
39	0	1	0	0
Totals	221	230	161	173

Spatial Distribution

The majority of both fresh and decayed carcasses were observed in the upper reach. Fifty-eight percent (n = 221) of the fresh carcasses and 57% of decayed carcasses (57.4% total) were (Table 7) observed in Reach 1. The ratios of fresh to decayed carcasses were 1:1 in Reach 1 and 1:1 in Reach 2.

Temporal Distribution

Fresh carcasses were observed from survey period 1 (5-6 May 1998) through survey period 38 (24-25 August 1998) (Table 1, Figure 5). The number of fresh carcasses observed during May fluctuated from zero (29-30 May 1998) to 10 (17-18 and 26-27 May 1998). The fresh carcass numbers gradually increased in June and peaked at 30 carcasses during the 1-2 July 1998 survey period. Fresh carcass numbers generally declined during the remainder of the study. About 66% of fresh carcasses were observed between 10 June 1998 and 23 July 1998.

Winter-run spawning occurred from late-April 1998 into mid-August 1998, assuming that fresh carcasses are available for observation approximately two weeks after spawning (Snider and Vyverberg 1995). Over 80% of spawning occurred from mid June 1998 through late July 1998; peak spawning occurred during early July (Figure 5).

Hatchery-produced Winter-run Chinook Salmon

Four adipose-clipped carcasses (2 fresh and 2 decayed) were collected (Table 8). CWTs were only recovered from the two fresh carcasses. Data from the two CWTs revealed that the two salmon were winter-run chinook salmon produced at CNFH. One CWT was recovered on 14 June 1998 (Tag # 05-01-01-10-06) from an 84 cm FL, 4-year old (1994 brood year) male. The other CWT was recovered on 9 August 1998 (Tag # 05-01-01-14-15) from a 61 cm FL, 3-year old (1995 brood year) female.

Table 8. Summary of adipose-clipped (hatchery-produced) carcasses collected during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1998.

Date collected	Tag number	Sex	FL (cm)	Brood year
June 13	no tag[1/]	Female	63	?
June 14	05-01-01-10-06	Male	84	1994
June 29	no tag[1/]	Female	65	?
August 9	05-01-01-14-15	Female	61	1995

1/ No tags were recovered from the decayed carcasses. The CWT may have been lost due to the carcasses decayed state, or the adipose clip may have been false, caused by the decay.

DISCUSSION

The results of three years of carcass surveys cannot by themselves address the issues of habitat availability relative to flow and other attributes of physical habitat. Several more years of survey are needed. These data should then be compared with redd survey data to identify salmon spawning habitat requirements. The low population level may also reduce the efficacy of the population surveys in evaluating habitat needs. If the population is so low relative to habitat availability, little can be determined with these data alone, especially relative to the habitat conditions necessary to support the targeted, recovery population of at least 20,000 fish (NMFS 1996). However, if habitat is limiting at these low populations, habitat-flow relationships should be identifiable. Other studies that will augment this component of the overall investigation may include aerial photographic surveys of redds, physical habitat modeling, and focused evaluation of the hydraulic and substrate attributes of spawning habitat.

Population Estimates

Law (1994) found that the Petersen model consistently showed substantially larger overestimation than either the Schaefer or Jolly-Seber models. When both fresh and decayed carcasses are used, he found that the Petersen model overestimated the known population by as much as 151%, and by as much as 84% when only fresh carcasses were used. He assumed a catch (recovery) rate of 40%, a tagging rate of 90%, and survival or carry over rates for each consecutive recovery period of 80%, 40%, 20%, and 0%. We used both fresh and decayed carcasses to derive the estimate of 6,479 winter run. Using just fresh carcasses, the estimate is 5,501. Law found that the Schaefer model also overestimated the known population by 78% when both fresh and decayed carcasses are used, and by 52% when only fresh carcasses are used. The altered Schaefer model using fresh carcass data provided an estimate of 4,653. All three estimates likely overestimate the true population.

The most appropriate winter-run escapement estimate to provide population trends is the one derived from the Petersen formula using fresh carcass data. Although this model will likely overestimate the true population, data will likely be available every year to permit calculation of a population estimate, unlike the Schaefer and Jolly-Seber models. Unless winter-run population is maintained at greater numbers, there will not be enough tag recoveries to allow use of the Jolly-Seber or Schaefer models in most years even though these models would provide a more accurate estimate.

One of the goals for the 1998 survey was to improve upon the recovery rate observed during the earlier two surveys (12% in 1997 and 15% in 1996). The overall 1998 tag recovery rate, however, was still only 13%. Probable reasons for low tag recoveries include poor visibility and high flows. Reduced visibility during part of May combined with flows that increased from 10,000 cfs on 5-6 May to 23,500 cfs on 29-30 May hampered early carcass recovery efforts. Tag recoveries were low until 10 June and then showed an increase concurrent with improved water clarity and declining flows (Figure 6).

In contrast, recovery rates for upper Sacramento River fall-run chinook salmon during the 1995 through 1997 escapement surveys ranged from 26% to 33%. Flows during the fall-run survey periods are typically around 5,000 cfs, which are much less than during the winter-run surveys (Snider et. al. 1997).

Effective Spawner Population

The effective spawner population is defined as the estimated number of females that spawned, assuming there were enough males to service all the redds. Since 90% of the carcasses used to estimate adult escapement were female, the estimated female population based on the carcass survey was 4,852 (based on Petersen formula using fresh carcass data). Prespawning mortality was 5% yielding an estimated effective spawner population of 4,609.

Sex Composition

The ratio of males to females observed during the carcass surveys was 1:7.5 compared to 1:3 during 1997 and 1:6.4 during 1996. The sex ratio varied throughout the survey ranging from 1:2.4 in May (n = 57), 1:6.1 in June (n = 127), 1:22.1 in July (n = 162) and 1:13.0 in August (n = 28).

The following are possible explanations for the observed difference in sex composition:

1. The recovery rate of males is less than for females. In a carcass survey and weir count conducted on Bogus Creek, a tributary to the Klamath River, the recovery rate of adult males was 11% less the rate for females (Boydstun 1994).

2. If a high portion of the male population leaves the ocean as 2-year-olds, the male to female ratio of that age class remaining in the ocean is reduced significantly. Based on the age composition criteria used in the NMFS model, 50% of the returning males would be grilse. Assuming an initial sex ratio of 1:1, this alone would result in a male to female ratio of nearly 1 to 2. As the proportion of males returning as 2-year-olds increases (x), the ratio of male to female adults for that age class decreases to 1:(1/1-x) (e.g., if x = 0.5, the ratio is 1:2; if x = 0.7, the ratio is 1:3.3, *etc.*).

3. A combination of the above two factors would produce an even greater disparity between adult males and females.

Comparison with Red Bluff Diversion Dam Winter-run Escapement Estimates

Results of the salmon counts at RBDD indicated an estimated 2,612 in-river produced winter run, including 1,784 adult and 828 grilse, migrated to the upper Sacramento River (DFG unpubl. data). RBDD data also indicate that an estimated 15 hatchery-produced winter run migrated to the upper Sacramento River. The male to female ratio for adults was not reported.

Adult escapement estimated from the carcass survey data was 2.5 to 3 fold greater than the RBDD estimate. The disparity may be explained by the fact that both the Petersen and Schaefer models typically overestimate escapement when applied to carcass survey data. However, it is unlikely that we would observe 769 adult salmon, nearly 45% of the total number of adults estimated to pass RBDD, especially since some winter run spawn downstream of the survey reach and some likely died before spawning. Also, it is unlikely that collecting, marking then returning the carcasses to the river would bias recovery to the extent that we observe carcasses from nearly one of every two winter run that spawn in the river, but can recover less than one of every six salmon that we mark. For the two methods to produce equivalent estimates, we would have needed to recover over 40% of the marked carcasses, an extremely high recovery rate. As such, it is likely that not only does the carcass survey over estimate the population, but that the RBDD estimate is low.

Another possible explanation for the disparity is that the percentage of fish moving past RBDD during the counting period was less than the estimated 13.4% (assuming the RBDD estimate is low). To evaluate the estimated proportion of the run that passed RBDD during the counting period, we conducted a sensitivity analysis using estimates of adipose-clipped winter run made at RBDD and subsequently in the upper river system (Snider et al. 1998). The estimated number of adipose-clipped winter run returning to the upper drainage was 113. One hundred hatchery-produced winter run were estimated to return to Battle Creek (S. .Hamelberg, FWS, unpubl. data), and 13 hatchery-produced winter run were estimated to have spawned in the Sacramento River survey area (carcass survey results). The escapement of hatchery-produced winter run based on RBDD counts (15) was less than 15% of the upper basin estimate. The RBDD estimate was based on the expansion of a count of 2 adipose-clipped fish and the assumption that the counting period accounted for 13.4% of the total migration. If we assume that the actual number of hatchery-produced winter run migrating past RBDD was at least 113, as described above, then the proportion of the run counted at RBDD was no more than 2/113, or 1.7%, compared to 13.4%. Note that the proportion of fish moving past RBDD after 15 May (measured between 1969 and 1985) is quite variable and the proportion of 1.7% lies within the observed range (Figure 7). Assuming that 1.7% of the in-river produced (non-clipped) winter run also passed RBDD during the counting period, (i.e., 350 salmon represents 1.7% of the winter-run population passing RBDD), the estimated number of in-river produced winter run passing RBDD becomes 20,588 (350/.017), comprising 14,062 adult and 6,526 grilse.

Results of this analysis suggest that there are some major errors in either the assumptions (i.e., that the migration timing of in-river and hatchery produced winter run is comparable as used in the RBDD estimate and in our sensitivity analysis), or in the estimates of adipose-clipped salmon, or both. The errors may simply be due to a very small number of adipose-clipped fish returning to the system that in turn amplifies any differences between the two estimates.

Estimates of adipose-clipped winter run entering Battle Creek in 1998 were not based upon video counts, as in the past, due to high flows preventing such counts. As such, the estimate in Battle Creek was less accurate, but details of the estimate are unavailable for further discussion. The estimated number of adipose-clipped fish entering the carcass survey area was likely high.

However, the number was so low that even assuming that all adipose-clipped fish using the area were observed (i.e., only two clipped salmon entered the area) the influence on the sensitivity analysis, above, is negligible. Conversely, a small change in the count at RBDD can substantially change the adipose-clipped winter-run estimate and subsequent analysis. For example, if two more clipped fish were observed at RBDD, the estimate doubles, at least, decreasing the estimated percentage of the run passing RBDD in our sensitivity analysis from 1.7% to 3.5%, which decreases the estimated adult population to 6,830. As such, it should be noted that 3% (two of the 65) winter run captured in the RBDD trap were adipose clipped, but the estimated proportion of adipose-clipped fish passing RBDD was less than 0.6% (15 out of 2,627). The difference is due to the expansion of fish counted, by video and by direct observation. No adipose-clipped fish were counted beyond those in the trap. The potential for missing a clipped fish likely exists which could substantially change the clipped salmon estimate. Regardless of the reasons, the data used to conduct a sensitivity analysis of the 1998 winter-run escapement estimates are deficient, and the analysis results do not reduce the uncertainty as to the accuracy of the estimates.

The disparity in estimates of adult winter-run escapement is even further exaggerated when comparing effective spawner population estimates. The effective spawner population estimated using the RBDD data (assuming a 1:1, female:male ratio and 5% prespawning mortality) is 1,202. The effective spawner population estimated using the Petersen model results is 4,449 and 3,707 using the Schaefer model estimate. Since some portion of the population migrating past RBDD dies, or otherwise does not reach the spawning survey area, the RBDD estimate should exceed the number of fish expected to spawn in the survey area. However, the carcass survey estimates are three to nearly four times the RBDD estimate.

One distinct difference between the carcass survey and RBDD count that influences the estimate of the effective spawner population is the criteria used for distinguishing adult and grilse. At RBDD, grilse are defined as salmon < 65 cm FL. The length frequency analysis used to differentiate grilse and adult in the carcass survey suggests that a substantial portion (24%) of the female adult population was < 65 cm FL. (The discrepancy could also account for the relatively high proportion of grilse in the RBDD [31.7%] versus only 2% in the carcass survey). If we adjust the RBDD population data to reflect the carcass survey findings, (i.e., 1,202 females represents 76% of the adult female population), the RBDD effective spawner estimate increases to 1,581 females. The differences between the two estimates are substantial.

RECOMMENDATIONS

1. The mark and recapture carcass surveys should be continued to compliment RBDD counts and potentially improve application of the results in identifying escapement numbers and eventually winter-run habitat relationships in the upper Sacramento River.

2. Investigate the discrepancies between the sex ratios observed during the carcass survey and the fish trapped at RBDD.

3. One of the principal questions that needs to be addressed is whether there is a difference in the availability of male and female carcasses to our sampling procedures. One possible explanation for the low male to female ratio observed in 1996 and 1997 is due to post- spawning behavior differences. Males may move downstream or to areas unavailable to sampling (e.g., deep pools), while females stay on the redd until they die and therefore are more susceptible to sampling. An effort should be made to determine if the ratio of male to female carcasses in deep (pool) areas is different from that observed in our surveys. This could be done several times throughout the spawning season using video surveillance or diving.

3. The length at age criteria used to identify the age of female and male winter run should be verified using scales and otoliths collected from the sampled carcasses.

4. The methods used to estimate adipose-clipped fish passing RBDD and in the upper river system need to be addressed relative to the utility of the appropriateness of the sensitivity analysis discussed herein as a tool for adjusting RBDD and carcass survey results.

5. The RBDD count data collected from 1969 through 1998 should be further evaluated to determine the validity of using a four-year mean to describe the proportion of winter run passing RBDD once the gates are closed.

6. The 1996 through 1998 carcass survey data should be combined with RBDD and other appropriate data to address the best way to combine information to reduce uncertainty surrounding estimating winter-run escapement.

7. Comparison of winter-run juvenile emigration data with escapement data should be evaluated as another means of reducing uncertainty of escapement estimates.

ACKNOWLEDGMENTS

Survey data were gathered by: Vina Free, Jeffery Jahn, Jason Kindopp, Kirshnan Nelson, Randy Rickert, Chris Wilkinson, and Julie Zerr with the FWS; Chris Cox, John Galos, Mike Hendrick, James Lyons, Jordan McKay, Brian Sardella, Mike Spiker, Jada Simone-White with the DFG. Data were processed and summarized by Katherine Taylor of DFG. We thank those individuals for their efforts, as well as Frank Fisher for providing logistical and technical support and Jim Smith (FWS) for facilitating a cooperative investigation.

LITERATURE CITED

Boydstun, L. B. 1994. Analysis of two mark-recapture methods to estimate the fall chinook salmon (*Oncorhynchus tshawytscha*) spawning run in Bogus Creek, California. Calif. Fish & Game 80(1):1-13.

Croci, S. J. and S. Hamelberg. 1997. Evaluation of the Sacramento River winter chinook salmon (*Oncorhynchus tshawytscha*) propagation program in 1996. USFWS Report. U.S. Fish and Wildlife Service, Northern Central Valley Fish and Wildlife Office, Red Bluff, CA

Fisher, F. W. 1993. Historical review of winter-run chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento River, California. Dept. Fish & Game Inland Fish Div. Office rept.

Hallock, R .J. and F. W. Fisher. 1985. Status of Winter-run chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento River Dept. Fish & Game Anad. Fish Br. Office rept.

Law, P. M. W. 1994. A simulation study of salmon carcass survey by capture-recapture method. Calif. Fish & Game 80(1):14-28.

NMFS (National Marine Fisheries Service). 1996. Recommendations for the recovery of the Sacramento River winter-run chinook salmon. Nat. Marine Fish. Serv. Southwest Region, Long Beach CA. 228 p.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Canada Dept. of Environ., Fish. and Mar. Serv. Bull. 191. 382 p.

Schaefer, M. B. 1951. Estimation of the size of animal populations by marking experiments. USF&WS Bull. 52:189-203.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. 2nd. MacMillan, New York, N.Y. 654 p.

Slater, D. W. 1963. Winter-run chinook salmon in the Sacramento River, California with notes on water temperature requirements for spawning. U.S. Fish & Wildlife Serv. Spec. Sci. Rept. - Fisheries No. 461 9 pp.

Snider, B. and D. McEwan. 1992. Chinook salmon and steelhead trout redd survey, lower American River, 1991 - 1992, Final report. Calif. Dept. Fish & Game, Stream Evaluation Program, Envir. Serv. Div.

Snider, B., K. Urquhart, D. McEwan, and M. Munos. 1993. Chinook salmon redd survey, lower American River, Fall 1992. Dept. Fish & Game, Stream Flow & Habitat Evaluation Program, Envir. Serv. Div.

Snider, B. and K. Vyverberg. 1995. Chinook salmon redd survey, lower American River, Fall 1993. Calif. Dept. Fish & Game, Stream Flow & Habitat Evaluation Program, Envir. Serv. Div.

Snider, B., B. Reavis, S. Hamelberg, S. Croci, S. Hill, and E. Kohler. 1997. 1996 Upper Sacramento River winter-run chinook salmon escapement survey. Calif. Dept. Fish & Game, Stream Flow & Habitat Evaluation Program, Envir. Serv. Div.

Snider, B., B. Reavis, and S.Hill, 1998. 1997. Upper Sacramento River winter-run chinook salmon escapement survey. Calif. Dept. Fish & Game, Stream Flow & Habitat Evaluation Program, Envir. Serv. Div.

Taylor, S. N. (Editor). 1974. King (chinook) salmon spawning stocks in California's Central Valley, 1973. Calif. Dept. Fish & Game, Anad. Fish. Admin. Rep. No. 74-12. 32 p.

USF&WS, 1996. Escapement of hatchery-origin winter chinook salmon (*Oncorhynchus tshawytscha*) to the Sacramento River, California in 1995, with notes on spring chinook salmon in Battle Creek. U.S. Fish and Wildlife Service, Northern Central Valley Fish and Wildlife Service Office, Red Bluff, CA.

FIGURES

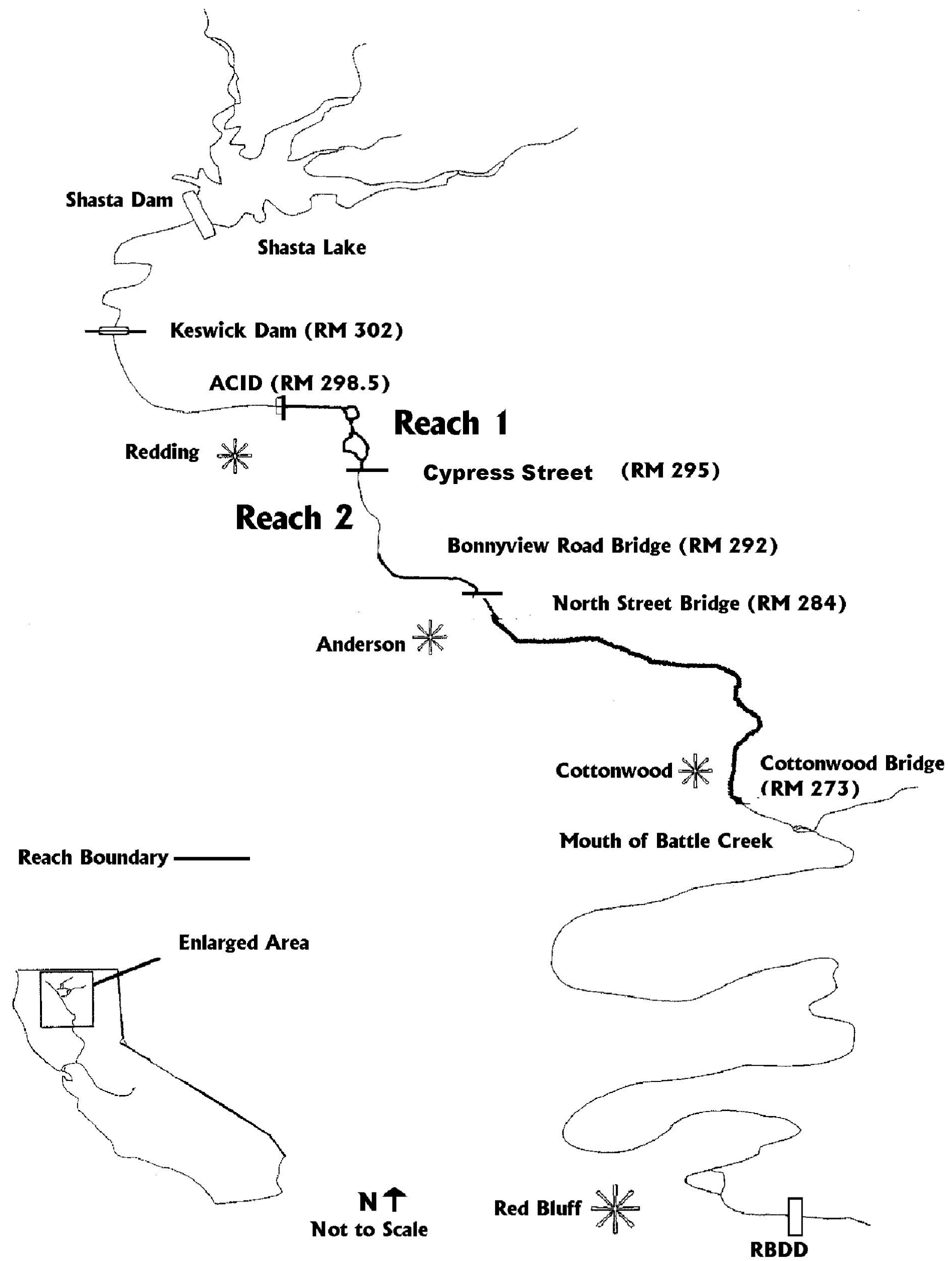

Figure 1. Upper Sacramento River winter-run chinook salmon escapement study location including reach designations, May - August 1998.

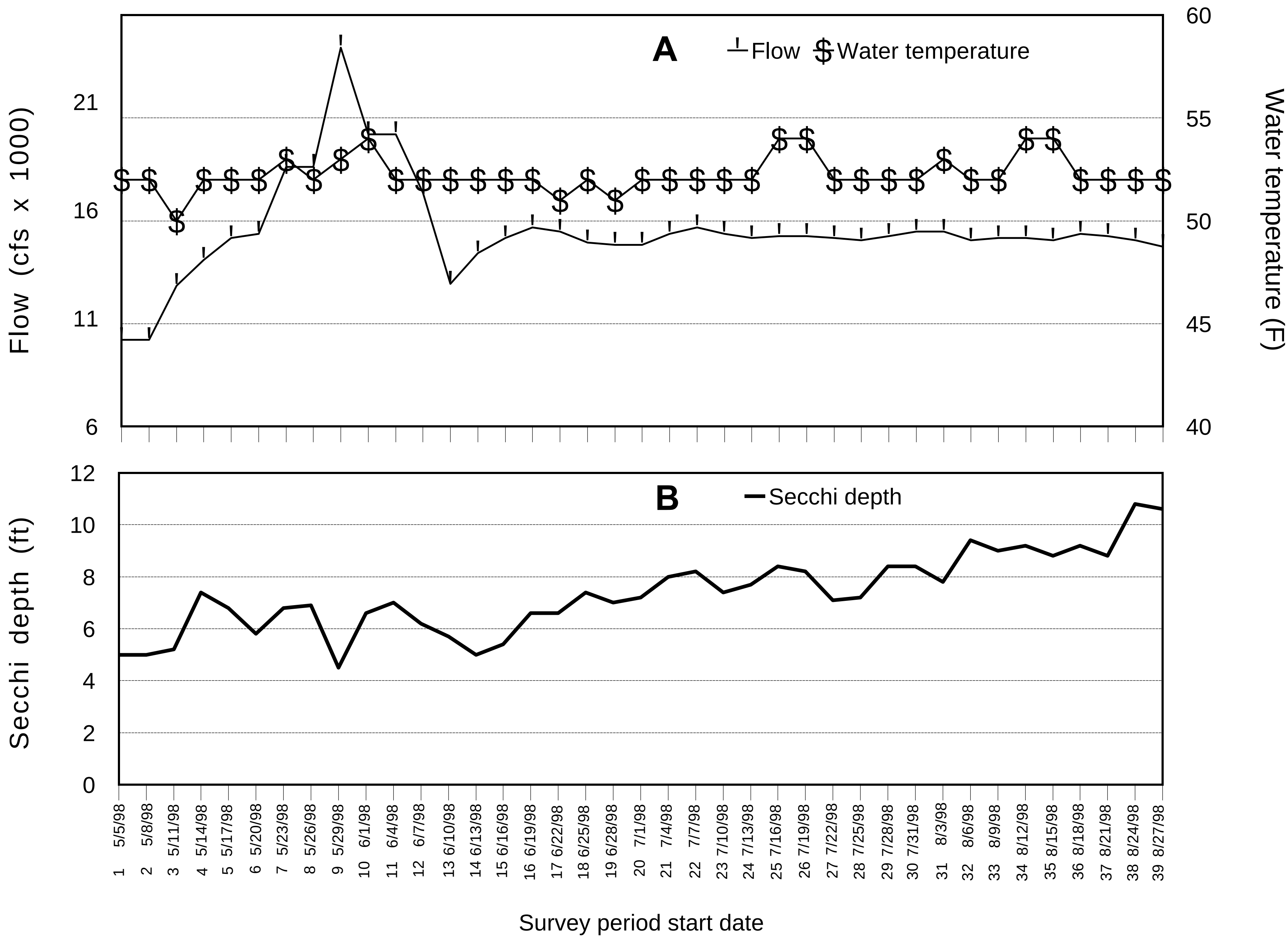

Figure 2. Mean flow and water temperature (A) and Secchi depth (B) measured for each survey period during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1998.

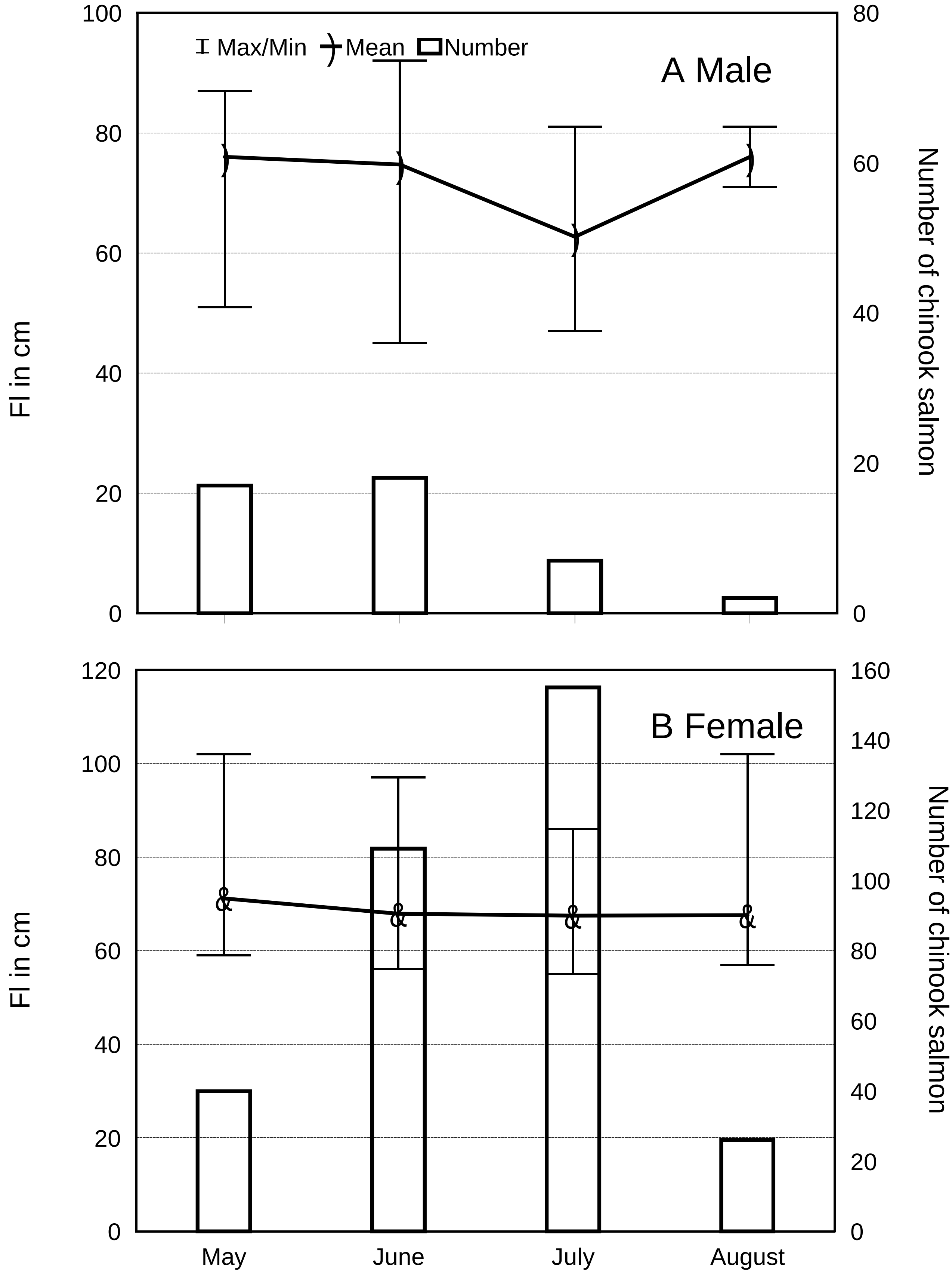

Figure 3. Catch and size distribution of (A) male and (B) female chinook salmon collected during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1998.

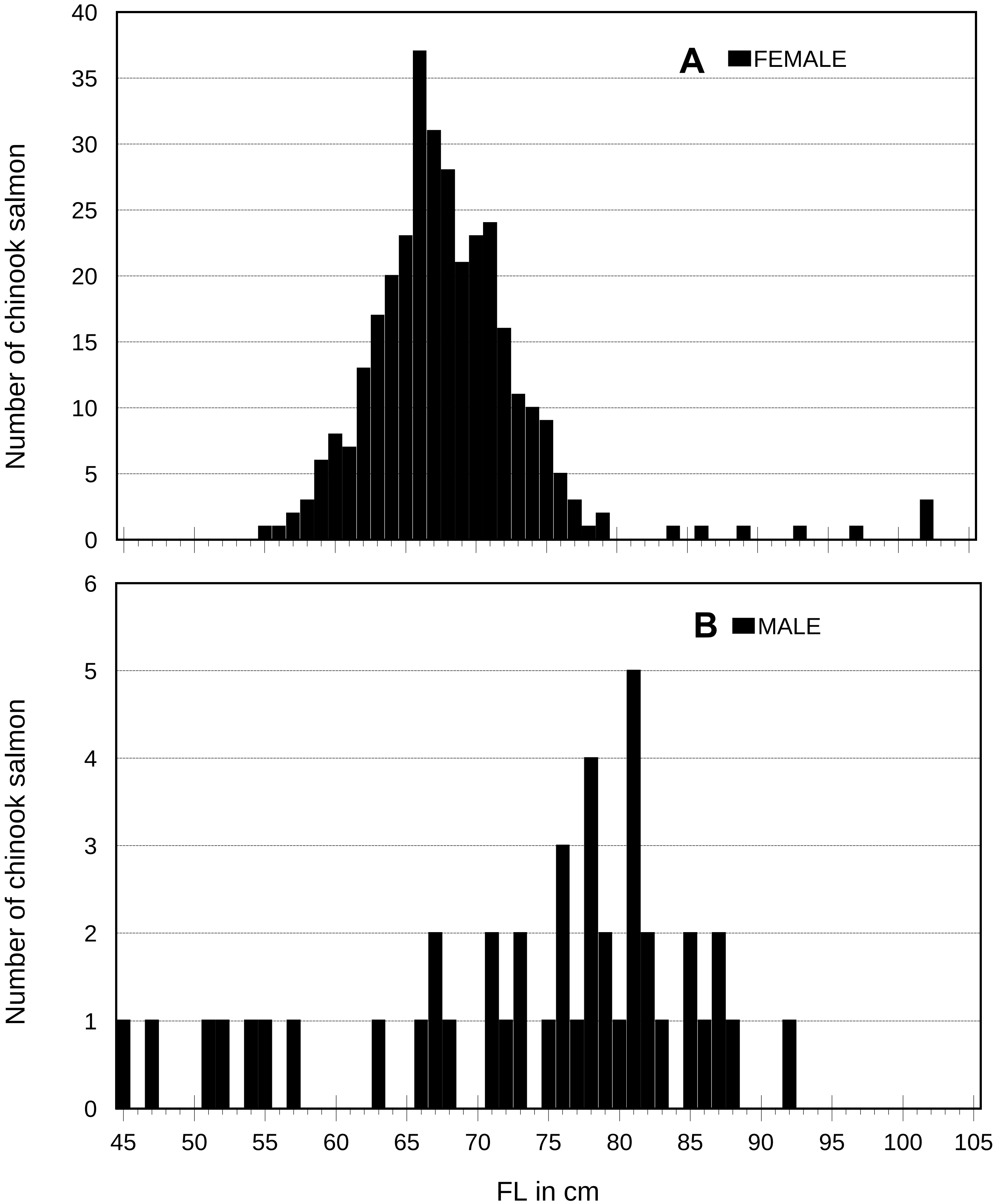

Figure 4. Length-frequency distributions for (A) female and (B) male salmon measured during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1998.

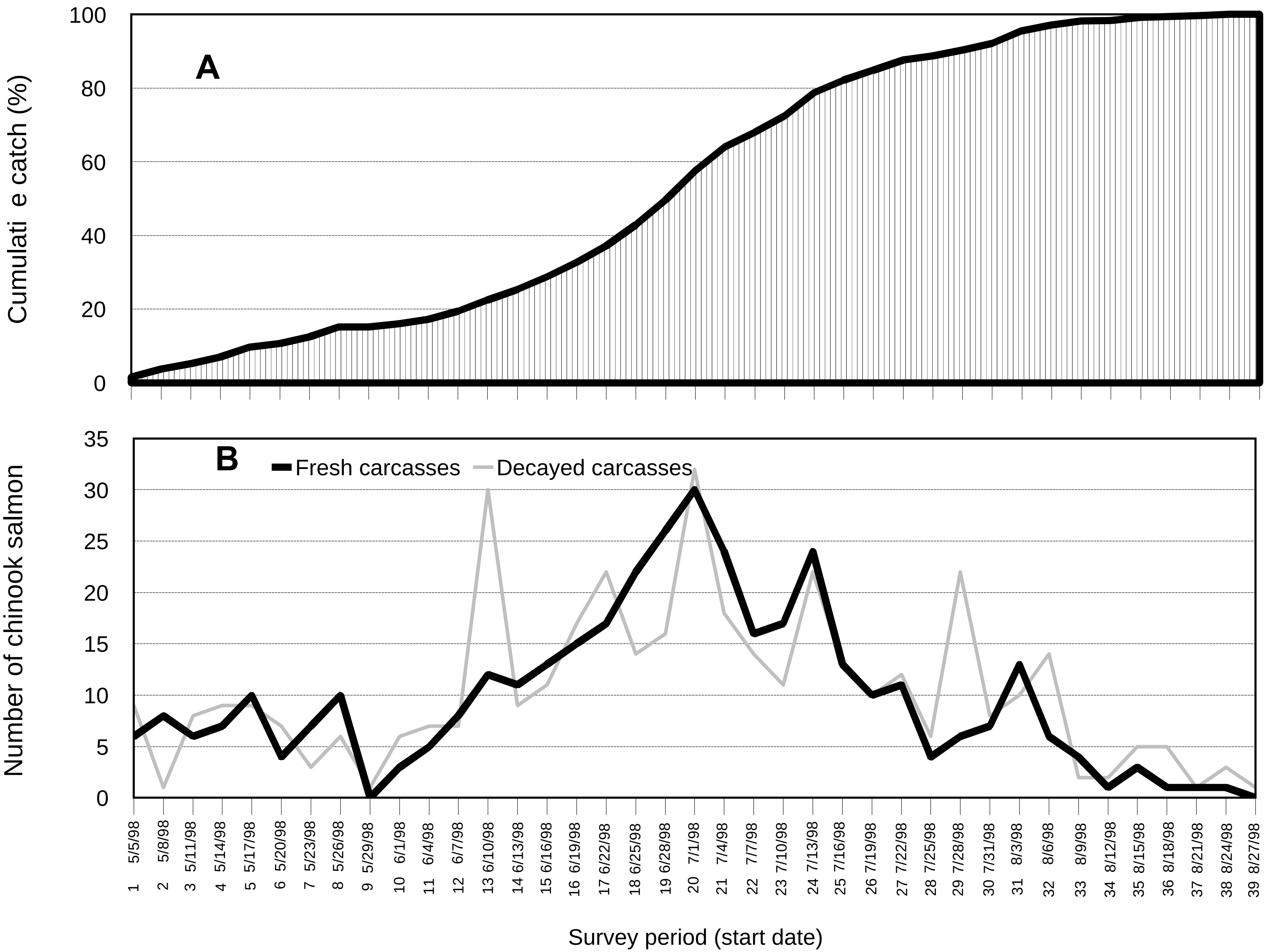

Figure 5. Cumulative catch of fresh carcasses (A), and catch distribution of fresh and decayed carcasses (B) , by survey period during the upper Sacramento River winter-run chinook salmon escapement survey, May-August 1998.

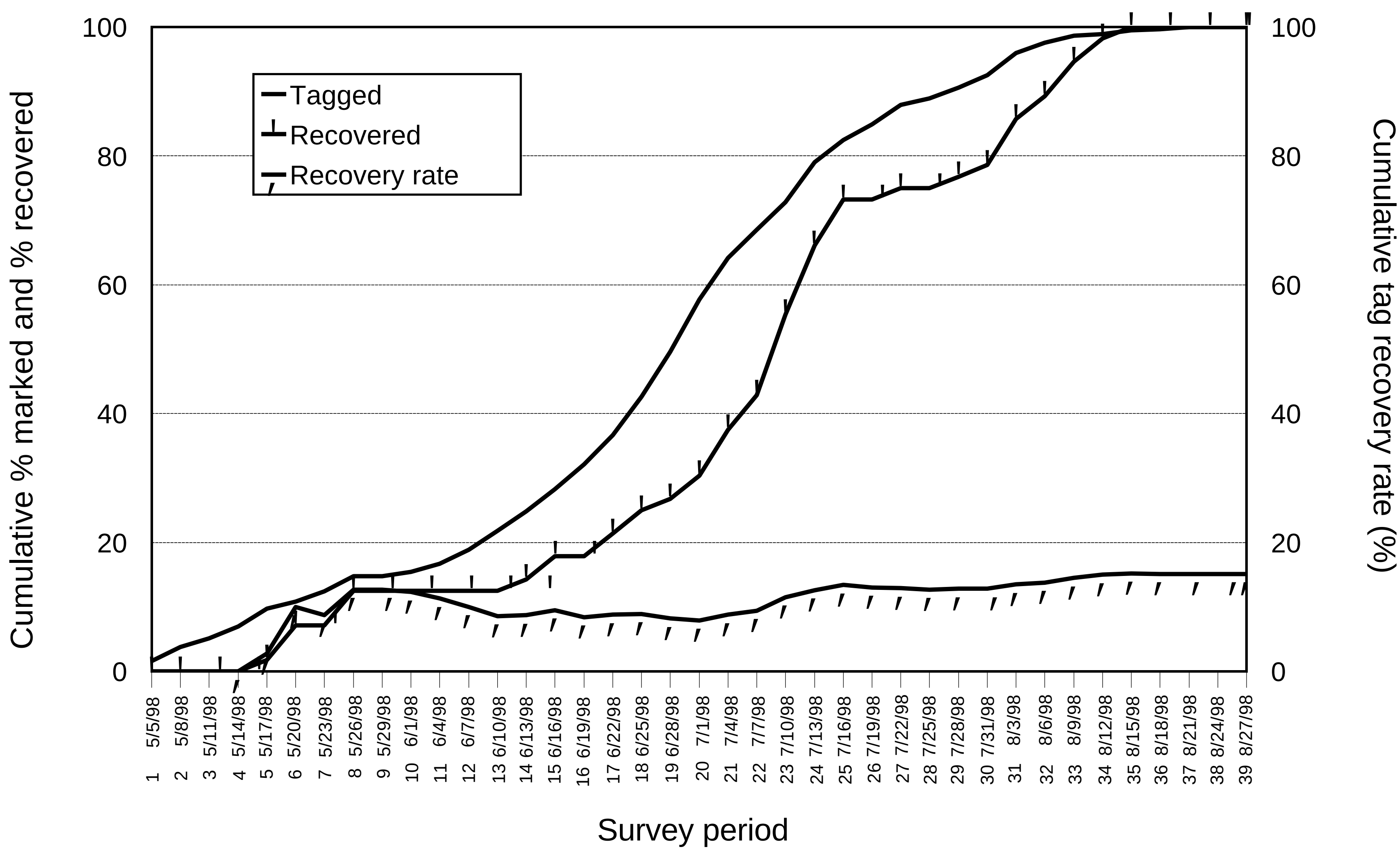

Figure 6. Comparison of temporal distribution of tagging versus recovering of tagged fresh carcasses and tag recovery rate (n tagged/n recovered) during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1998.

Figure 7. Percentage of the total migration of winter-run chinook salmon passing Red Bluff Diversion Dam after Week 20 (1969 through 1985).